G51B-0577

New methods for linking science objectives to mission architectures: A case study comparing single and dual-pair satellite gravimetry mission architectures

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Acknowledgements: A portion of this work was performed at Jet Propulsion Laboratory, California Institute of Technology, under contract with NASA. A portion of this work was funded under the Technical University of Munich (TUM) Global Incentive Fund.

MOTIVATION

C-1b. Determine the change in the global oceanic heat uptake to within 0.1 Wm^{-2} over the course of a decade	**Most Important**	Sea surface height	Space/Time Sampling: 7 km along track/10 day, equivalent to 150 km2/10 day; Space/Time Coverage: global/10 days; Accuracy/Stability: 3 mm@7km, 1 mm/global/yr
		Ocean mass distribution	Space/Time Sampling: 300 km2/monthly; Space/Time Coverage: global/monthly; Accuracy/Stability: 15 mm@300km2, 0.1 mm/yr/decade
		Ocean temp and salinity profile	Space/Time Sampling: 3degx3deg/10 day, equivalent to 150 km2/10 day; Space/Time Coverage: global/10 days; Accuracy/Stability: 0.01 deg/0.01 psu

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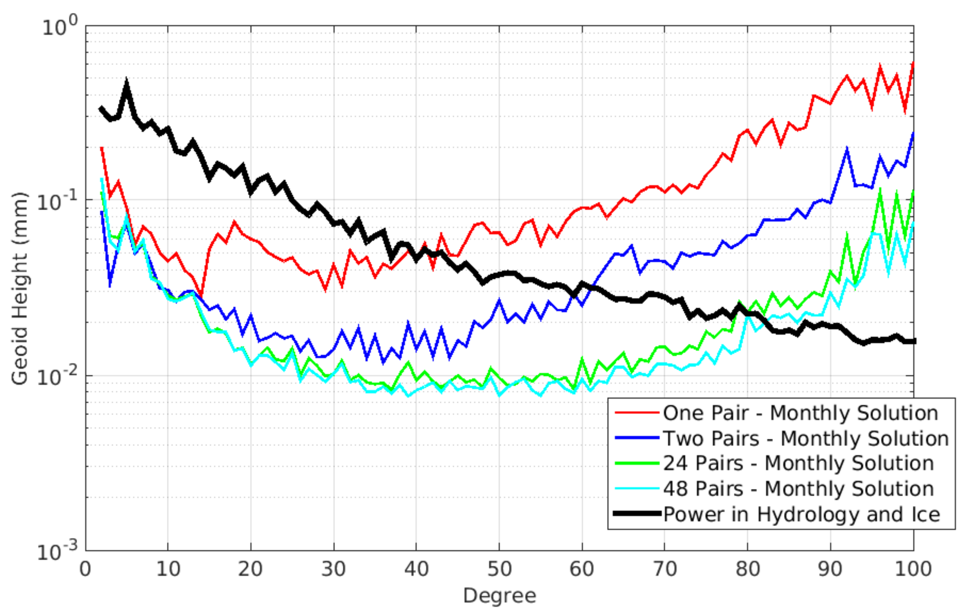
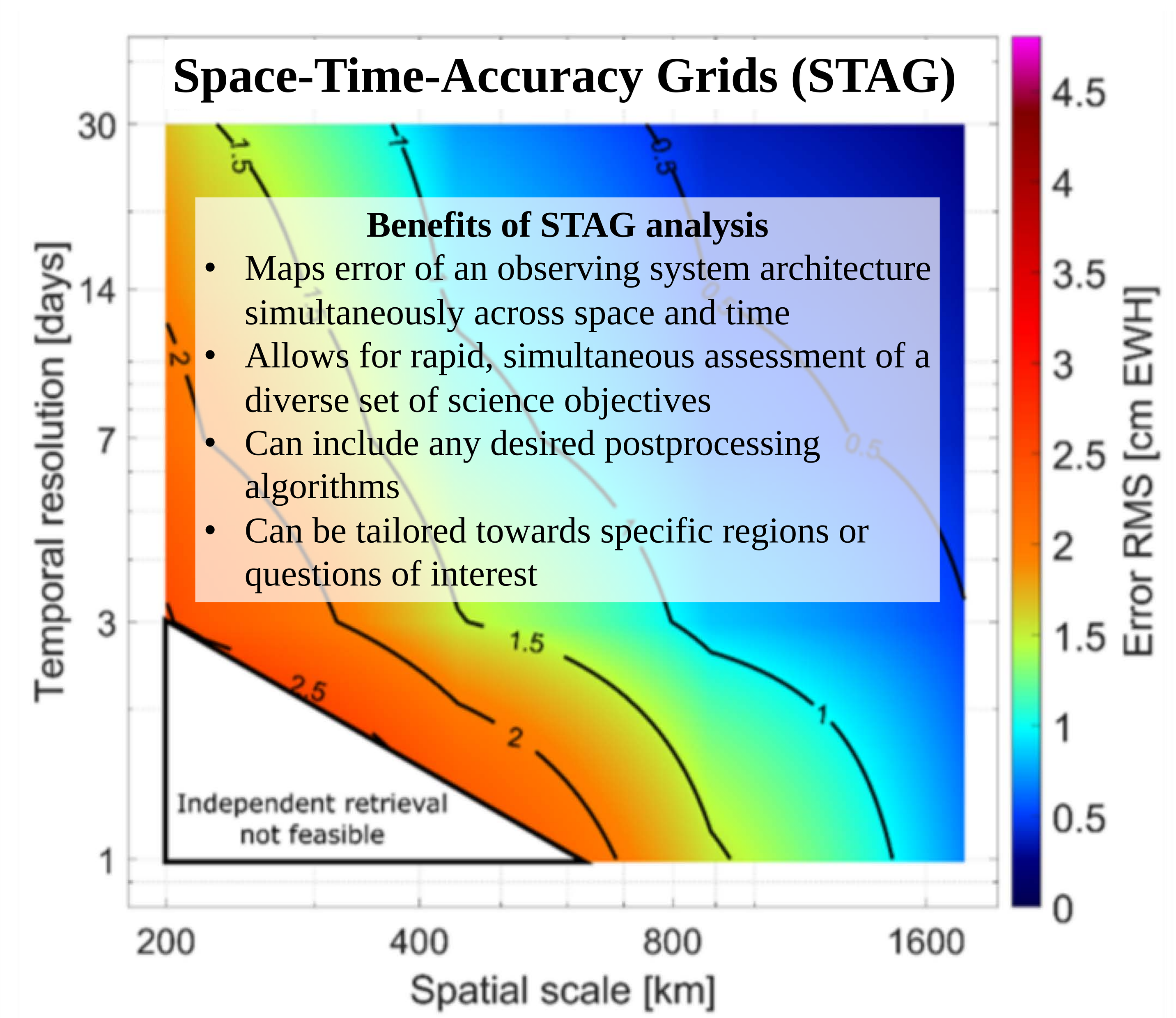
2017 ESAS Decadal Survey



Assessment of satellite gravimetry mission architectures is typically performed in the spectral domain using degree RMS analysis (left). However, science objectives (top) are usually expressed in terms of desired spatial and temporal resolution along with a targeted accuracy. **Here, we develop a new method call Space Time Accuracy Grids (STAG)** for which to easily relate science objectives to the performance of any observing system architecture (right).

Markus Hauk and David Wiese, "New methods for linking science objectives to remote sensing observations: a concept study using single and dual-pair satellite gravimetry architectures," *Submitted and in review*.



A CASE STUDY: SINGLE PAIR VERSUS DUAL-PAIR

Table 1. Mission architectures studied

Mission architecture	Altitude [km]	Inclination [degree]	Revolutions in one sub-repeat orbit	Right ascension of ascending node [degree]
Single Polar Pair	342	89	110/7	0.00
Two Polar Pairs	342	89	110/7	0.00
	342	89	110/7	14.45
Polar Pair + Inclined Pair ("Bender")	342	89	110/7	0.00
	352	70	109/7	89.99

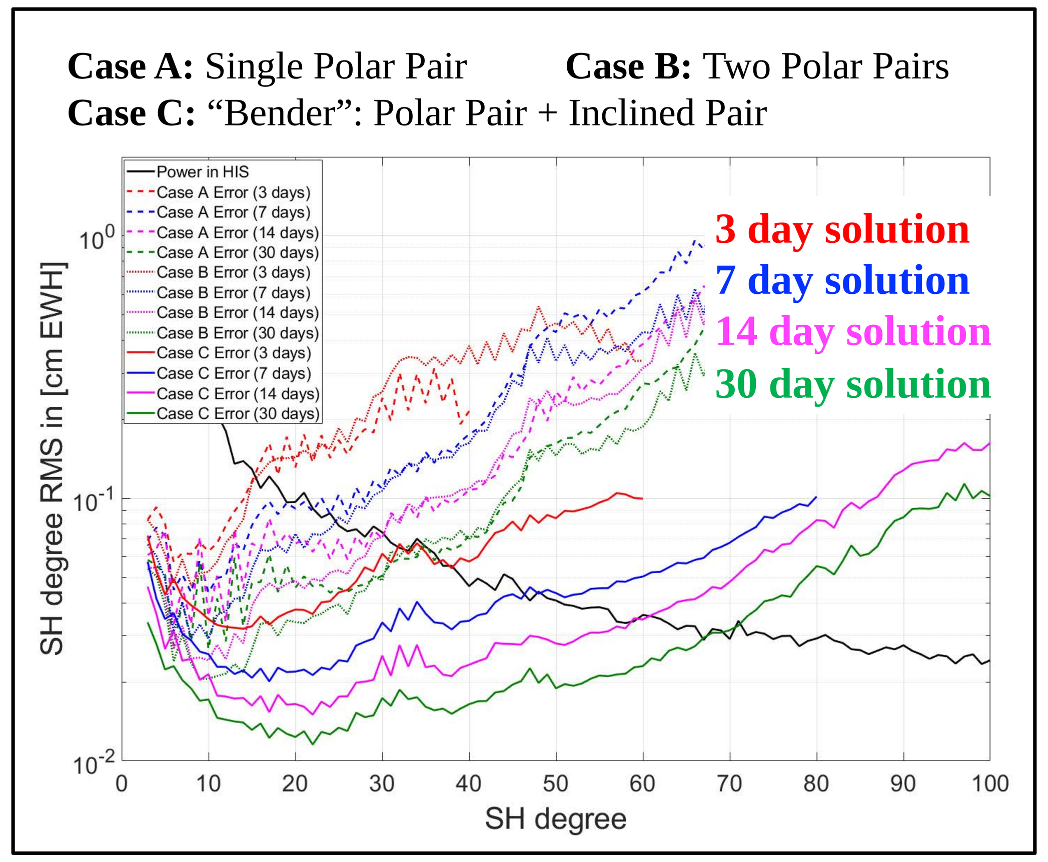
Table 2. Numerical simulation force model setup

Model type	Truth	Nominal
Static gravity field	GOCO05s	GOCO05s
Non-tidal time variable gravity field	ESA Earth System Model (AOHIS) 6-hr temp. res.	ESA Earth System Model AOerr + DEAL 6-hr temp. res.
Ocean tides	EOT11a	GOT4.7

Table 3. Retrieval periods for simulations

Retrieval period [days]	Single Polar Pair [SH degree/order]	Two Polar Pairs [SH degree/order]	Polar Pair + Inclined Pair [SH degree/order]
30	100	100	100
14	100	100	100
7	80	80	80
3	40	60	60
1*	-	10	20

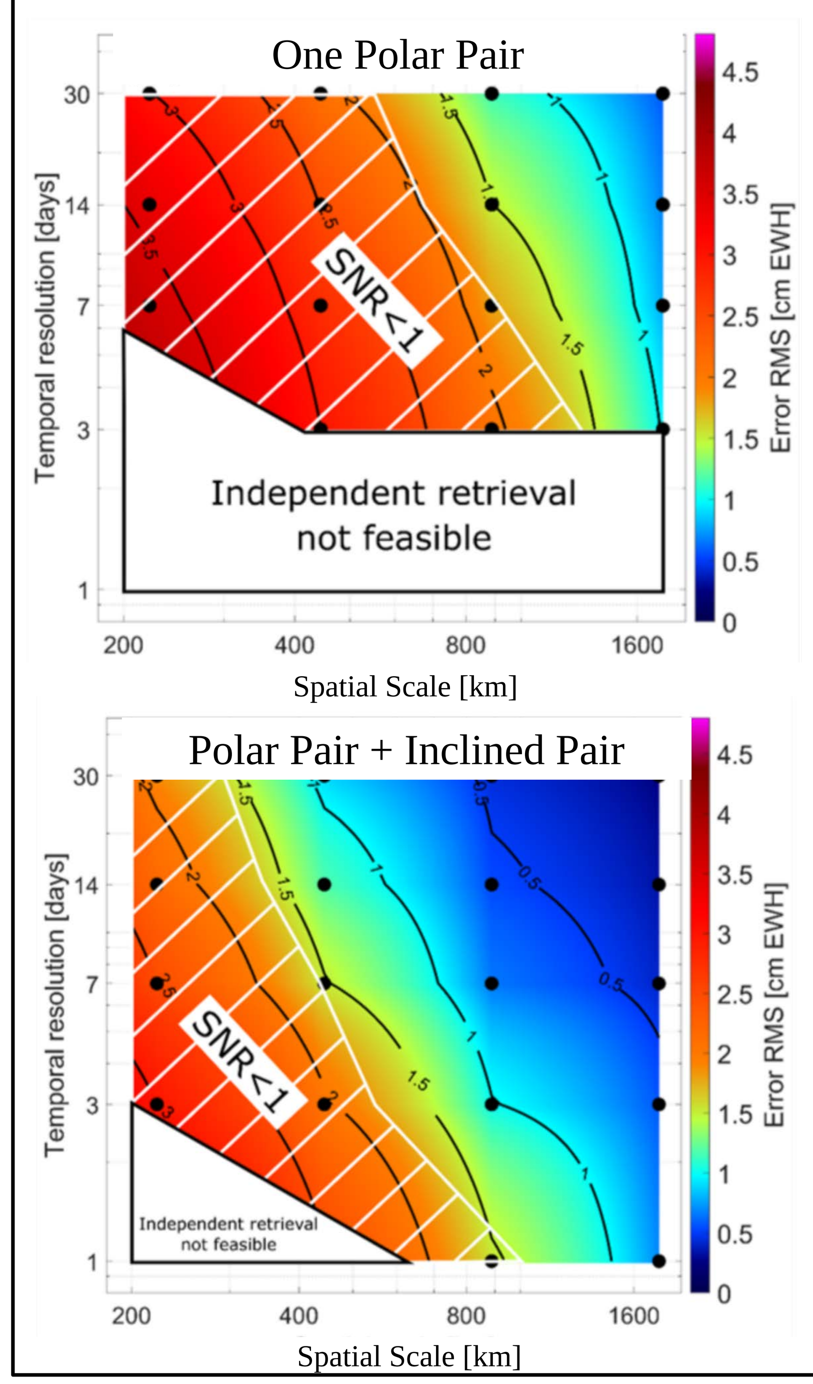
*co-parameterization

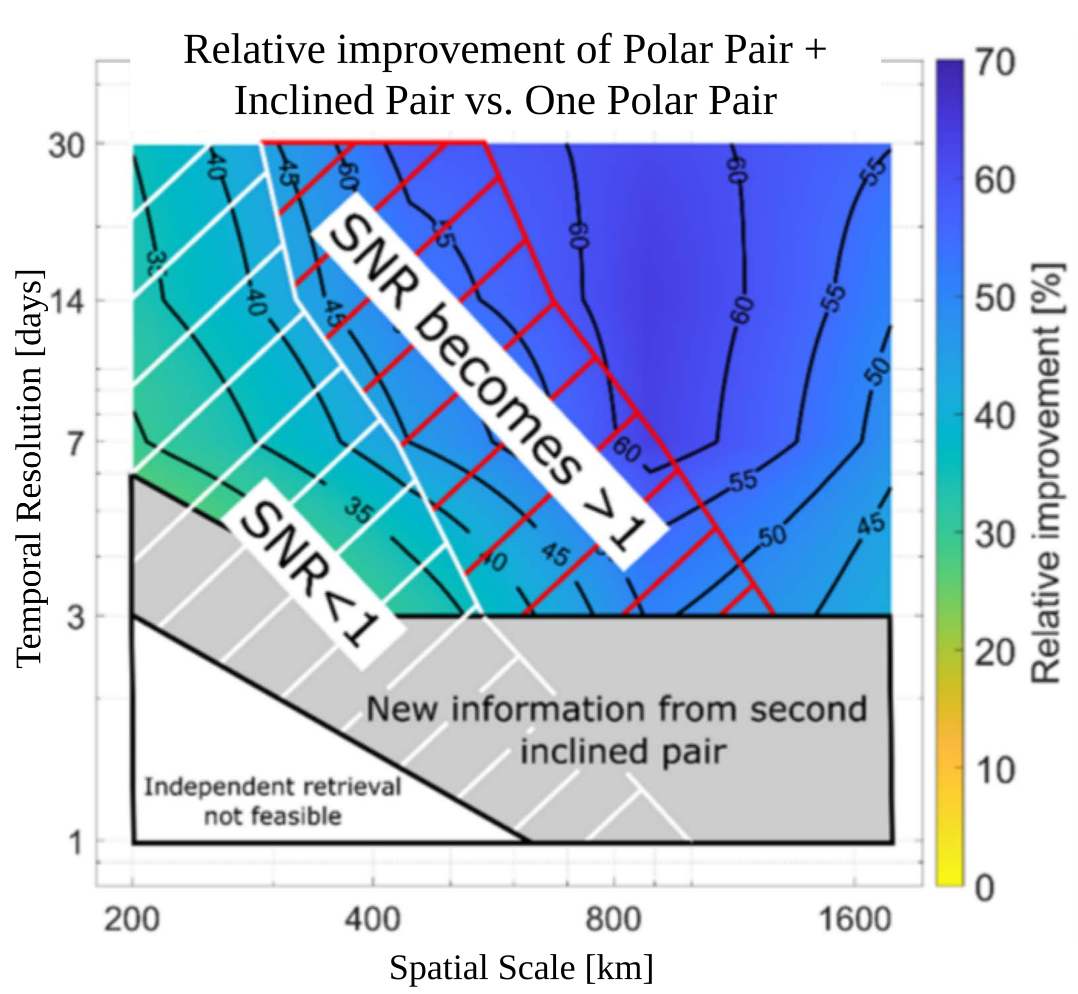


We run numerical simulations for architectures in Table 1 using the force models/simulation setup in Table 2. Instrument noise for an accelerometer, laser ranging system, attitude knowledge, and inertial position are all added using performance specifications roughly on par with GRACE-FO. Retrievals are made over multiple timeframes (Table 3). Degree RMS results are shown in **Figure 1** (top).

RESULTS

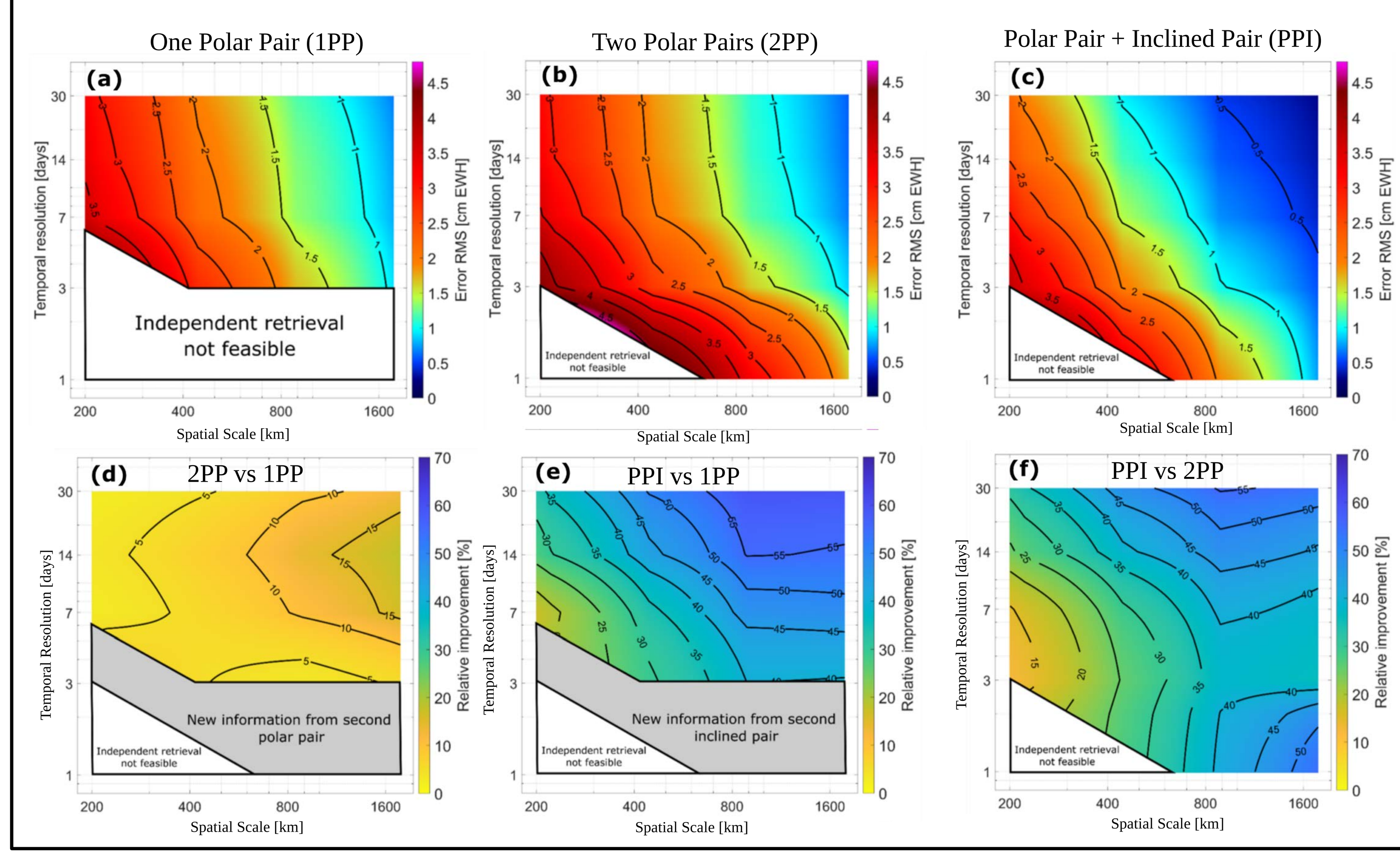
Global Raw Retrieval Errors: No Post-Processing





Here, we compare the raw gravity retrieval errors for each architecture. The plot above shows the relative improvement of the "Bender" architecture (bottom-left) versus the single polar pair architecture (top-left). We are able to distinguish space/time scales where the SNR changes from < 1 to > 1, as well as regimes where entirely new information is added. Improvements are shown to peak at around 60%, near 800 km spatial scales and time scales > 1 week.

Land Hydrology Only: With Postprocessing Applied



Here, we demonstrate the ability of STAG analysis for targeted studies, examining land hydrology signals with inclusion of state of the art post-processing methods. Once post-processing is taken into account, we see the "Bender" architecture offers improvements ranging from 25% - 55% over both the single and dual-polar pair architectures. Additionally, we see that two polar pairs offers only modest improvements over a single polar pair, with error reductions peaking at 15% for the largest spatial scales (> 1000 km). This highlights the importance of improving the sampling isotropy over simply increasing the sampling frequency.

General Conclusions Regarding Architectures

- Improving the sampling isotropy is more important than simply increasing the sampling frequency.
- Largest benefit in the Bender architecture is seen for spatial scales between 500-1200 km. This is roughly the regime where no post-processing is required for the Bender architecture, but is required for the polar pair architectures. This highlights the strength of observing signals directly rather than relying on post-processing
- Largest benefit of the Bender architecture is for longer averaging times. This is likely due to the improved observation geometry allowing for errors to average down quicker than for the polar pair architectures due to their less correlated nature.

METHODS

STAG creation begins with numerical simulation output from degree RMS (Figure 1).